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**EMPIRICAL STUDY: ORDER SHARING BETWEEN  
TRANSPORTATION COMPANIES MAY RESULT IN COST  
REDUCTIONS BETWEEN 5 TO 15 PERCENT**

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## Empirical study: Order sharing between transportation companies may result in cost reductions between 5 to 15 percent

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# Empirical study: Order sharing between transportation companies may result in cost reductions between 5 to 15 percent<sup>\*</sup>

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## Abstract

In the traditional situation, all transportation companies had their own clients and their own set of transportation orders. In a situation with *order sharing*, transportation companies mutually share their data on transportation orders. This enables a much better allocation of orders to the transportation companies than in the traditional situation. In this paper we discuss the economic and other consequences of order sharing. The conclusions in this paper are based on both a real-life case and a simulation study. The simulation study shows that due to order sharing transportation costs may decrease by 5 to 15 percent, and sometimes even more.

*Keywords:* Transportation, cooperation, order sharing, simulation.

*JEL code:* C60

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## 1 Introduction

In the Dutch road transport sector, empty hauling makes up 40 % of total truck-km (OECD/ECMT/IEA, 1999). Furthermore, Eurostat (2001) reports that the ratio of the number of tonne-km and the number of truck-km dropped by 18 % between 1980 and 1995<sup>1</sup>. This efficiency drop might be one of the reasons for the marginal profit margins that the transport sector reports. The sector is on a continuous search for opportunities to improve performance. This paper covers one possible way of performance improvement: order sharing. With order sharing, transportation

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<sup>\*</sup> The authors are very grateful to Wout Dullaert and Martine Cools for their helpful comments and suggestions.

<sup>1</sup> Unfortunately no exact data on load factors in the Netherlands are available (CBS, 2004).

companies mutually share order data for simultaneous planning, such that in the long run total market demand for transportation capacity matches better with supply.

In this paper we discuss the cost and other advantages of strategic alliances between road transportation companies through order sharing. Our main focus will be on the operational cost advantages. Moreover, we pay attention to the potential disadvantages of order sharing. The paper is further organized as follows. Section 2 provides a brief literature review. Section 3 presents a case study on order sharing between transportation companies that transport flowers to the Dutch flower auctions. In Section 4 we compare the transportation costs in a system *without* order sharing to the transportation costs in a system *with* order sharing by means of a simulation study. Also, we present in section 5 a sensitivity analysis to indicate the main drivers behind the cost difference between the two systems. The financial, organizational and other variables that play a role in order sharing are discussed in section 6. Finally, we conclude in section 7.

## **2 Literature**

As opposed to maritime shipping and air transportation, in which area the concept of alliances between competing companies is quite common, the road transportation sector has not yet adopted horizontal cooperation on a large scale (Vos et al., 2003). However, in recent years a number of order sharing initiatives between logistic service providers have been launched in Western Europe. We refer to Dullaert et al. (2004) for an overview of such initiatives. Their report also discusses the results of a questionnaire on horizontal cooperation that was sent to 1500 logistic service providers in Belgium, 1129 of which are road transportation companies. The most important conclusion that the authors draw from the questionnaire is, that Belgian logistic service providers indeed believe in the potential of horizontal collaboration to increase the productivity of their core activities. 81 % of the respondents agree with this proposition. The most important barriers to horizontal cooperation that they identified were:

- Difficulties in finding a trusted party to lead the cooperation (75 %)
- Difficulties in finding partners (69 %)
- Hard to guarantee a fair mechanism for allocating savings the participants (68 %)
- Hard to estimate the savings of the cooperation in advance (55 %)

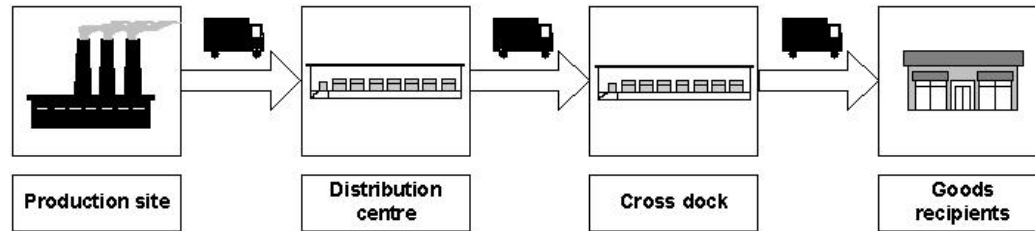
Vos et al. (2003) provide a real life case study on cooperation of seven Dutch producers of cookies and sweets. The producers all send their shipments to a central distribution centre, where they consolidate the orders. From there, a single logistic service provider transports the bundled shipments for individual clients, such that capacity utilization is optimised.

Besides the case study, Vos et al. provide a typology based on the objectives of the cooperation. They identified the following types of synergy:

- *Operational synergy* - limited cooperation to better utilise existing resources, e.g. order sharing to remove occasional inefficiencies due to empty return trips.
- *Coordination synergy* - cooperation of average intensity that tunes the needs of the logistic parties while keeping the existing network structure intact, e.g. a centralized planning system to optimise load factors of partners.
- *Network synergy* – long-term cooperation that incorporates changes in the network structure and joint investments, e.g. a joint distribution centre to decrease both inventory costs and the costs of consolidating orders.

Perhaps because horizontal cooperation in road transportation is new, the scientific research carried out on this topic is rather limited. Erdmann (1999) provides a discussion of the potential of consolidating shipments belonging to different shippers or transportation companies. This work includes the results of a simulation study for a number of scenario's (order-sets). The average savings in kilometres due to consolidation equal 10.71 %. However, no sensitivity analysis on these results is provided. Bahrami (2003) focuses on the cooperation between producers of consumer goods. Here, synergy in the transportation of goods of cooperating

producers is enforced by means of load consolidation. It is assumed that every producer has a distribution chain as depicted in Figure 1.



**Fig. 1.** Distribution chain studied in Bahrami (2003)

Bahrami considers two types of load consolidation: (1) consolidation at the distribution centre and (2) consolidation at the cross dock. He shows that the first option results in much higher savings than the second option. The following three-phase model for the analysis of a logistic cooperation between producers of consumer goods is proposed: (1) selection of suitable partners, (2) estimate on the savings in transportation costs due to cooperation and (3) an algorithm that gives an allocation of the realised synergy benefits among the partners.

This paper contributes to the literature by focusing on the second element of the three-phase model of Bahrami (2003). The savings in transportation costs are calculated for a case on order sharing for the Dutch flower auction and by a simulation study.

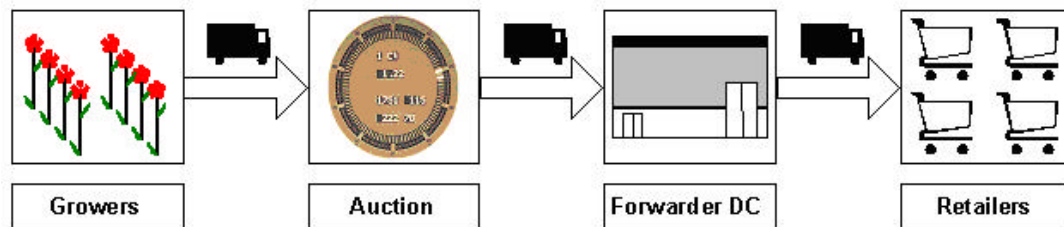
### **3 Case study: transport to the Dutch flower auction**

To illustrate order sharing in transportation we discuss a case study on the transport of flowers in the Netherlands. The Netherlands is the world's largest producer of cut flowers and plants, and accounts for more than half of the world's trade. In 2002 FloraHolland (<http://www.floraholland.nl/>) had a turnover of 1872 million Euros. It consists of five auction locations, 26 auction clocks, 3000 employees, and a broker that brings together supply and

demand of individual buyers and growers. Every day, 5000 Dutch as well as 3000 foreign growers supply products to the auction.

In the case study we focus on the transportation process of the Naaldwijk auction. This is the largest site of the Flora Holland Corporation and it is located in the centre of a large production area of flowers and ornamental plants. The total surface area is 65 hectares, 4.3 hectares of which is covered by cold storage rooms. At the Naaldwijk auction, 3 billion flowers and plants are sold on a yearly basis. This huge amount of products, together with the perishable nature of most flowers and plants, requires an efficient logistic process.

This process is depicted schematically in Figure 2. It starts at picking up flowers at the grower and the transport to the auction. When the flowers are sold, orders are collected and transported to the distribution centres of the logistic service providers. Finally, the flowers go from the logistic service providers to the retailer outlets.



**Fig. 2.** The logistic process of the Naaldwijk auction

Currently, 65 % of the total volume transported to and from the auction site is performed by about 40 third party transportation companies. The growers themselves transport the remaining 35 % of the volume to the auction. Altogether, each day approximately 2000 trucks deliver flowers to the Naaldwijk auction. The objective of this case study is to show that the process could be made more efficient by means of order sharing.

We compared two cases. In case one, two transportation companies that operate for the Naaldwijk auction each deliver the transportation orders of their own clients only. In case two, the



transportation orders of both companies are combined and simultaneously assigned to routes. We then calculate the cost difference between these two cases.

We assume fixed costs of € 274 per truck per day and variable costs are € 1.42 per kilometre travelled (NEA, 2003). The trucks used by the transportation companies have a capacity of 13 collies, while the average order size is 3.5 collies. Finally, each pick-up and each delivery takes 30 minutes.

Date	Carrier 1				Carrier 2				Order sharing				savings		
	Orders	Km's	Trucks	Cost	Orders	Km's	Trucks	Cost	Orders	Km's	Trucks	Cost	Km's	Trucks	Cost
05/20/03	140	831	5	2551	130	1342	10	4645	270	2104	15	7097	3.3%	0.0%	1.4%
05/21/03	78	1805	15	6674	302	1975	15	6915	380	3730	28	12969	1.4%	7.1%	4.8%
05/22/03	105	1010	8	3626	236	4720	32	15471	341	5651	39	18710	1.4%	2.6%	2.1%
05/23/03	169	791	6	2767	42	595	5	2215	211	1193	9	4160	16.2%	22.2%	19.8%
05/24/03	59	1061	7	3424	111	1992	13	6390	170	2728	18	8806	11.9%	11.1%	11.5%
05/25/03	70	1364	9	4403	253	3109	26	11539	323	4305	33	15155	3.9%	6.1%	5.2%
05/26/03	61	1266	8	3990	104	1440	12	5333	165	2615	18	8645	3.5%	11.1%	7.9%
07/22/03	53	1955	13	6338	37	3733	25	12150	90	5240	36	17304	8.5%	5.6%	6.8%
07/23/03	98	1343	10	4648	96	1355	11	4938	194	2621	19	8928	2.9%	10.5%	7.4%
07/24/03	52	591	5	2209	72	840	7	3111	124	1383	11	4978	3.4%	9.1%	6.9%
07/25/03	101	1445	11	5066	41	556	5	2159	142	1960	14	6620	2.1%	14.3%	9.2%
07/26/03	240	3453	26	12027	104	1507	11	5155	344	4544	36	16317	9.2%	2.8%	5.3%
07/27/03	39	755	5	2441	26	386	3	1370	65	972	7	3298	17.3%	14.3%	15.6%
07/28/03	45	759	5	2447	65	866	7	3147	110	1562	12	5506	4.0%	0.0%	1.6%
08/14/03	46	651	5	2295	30	737	4	2142	76	1231	9	4214	12.8%	0.0%	5.3%
08/15/03	90	1400	10	4728	103	1346	11	4925	193	2537	20	9082	8.2%	5.0%	6.3%
08/16/03	102	1880	12	5957	74	1480	9	4568	176	2902	20	9601	15.8%	5.0%	9.6%
08/17/03	112	1551	11	5217	74	983	8	3587	186	2363	18	8287	7.2%	5.6%	6.2%
08/18/03	44	1551	11	5217	93	983	8	3587	137	2363	18	8287	7.2%	5.6%	6.2%
Averages													7.4%	7.3%	7.3%

**Table 1.** Order sharing in flower transport

The results of the cost comparison can be found in Table 1. Due to the increased economies of scale, more efficient routes can be constructed. This leads to both a smaller number of trucks needed and a reduction in kilometres driven. The results show that order sharing and joint route planning led to a decrease of 7.3 % in both the number of trucks needed and total cost. However, there is much variation in the savings. In section 5 we discuss the influence of a number of important problem characteristics on the savings in cases with order sharing.

## 4 Simulation study

In the simulation study we consider a transportation system with multiple clients and multiple transportation companies. The clients place transportation orders for goods that are to be shipped from a single distribution centre to the client locations. It is assumed that no pick-ups take place, i.e. all orders are deliveries. The transportation companies own the trucks and the employees to carry out the orders. Further characteristics of the datasets that we generate for the simulation study are described in Table 2.

Purpose of the simulation study is, to compare the cost of a traditional transportation system *without* order sharing to the cost in a system *with* order sharing.

In the system without order sharing, each client is assigned to a single transportation company. This is implemented by successively assigning the randomly generated orders to the transportation companies, until a pre-set market share has been reached. In the system with order sharing, total system costs are minimised by constructing a joint route planning for the transportation orders of all companies. Side constraint for both systems is, that no orders may be left unplanned.

For the system *without* order sharing, we solve a Vehicle Routing Problem (VRP) for each transportation company to plan all orders that were assigned to this company. This is done with the *RitOpt* heuristic (Fleuren and Janse, 1993), which is the backbone of the route planning software *RitPlan* that is widely used by Dutch road transportation companies. For the system *with* order sharing, we apply the same heuristic to the complete set of client orders.

### 4.1 Base case

We develop a *base case scenario* with the variables set as displayed in Tables 2 and 4. For an explanation of the value of the clusteredness of demand points, we refer to the appendix. This base case serves as a starting point for the sensitivity analysis in Section 5.

Variable	Simulation values
Number of orders	200
Average of uniform order size distribution	50
Clusteredness of demand points	0.5
Number of transportation companies	3
Market shares	All equal

**Table 2.** Characteristics of base case

For the base case we calculate both for the system *with order sharing* and for the system *without order sharing* the following performance indicators:

- Total fixed and variable transportation costs
- Number of kilometres travelled
- Number of trucks used
- Load factor of the trucks

The results of the simulation are shown in Table 3 and Figure 3. They are based on 50 simulation runs. It turns out that on average in the base case order sharing results in a 12.3 % cost reduction, when compared to the traditional situation. This is a result of better coordination between demand and supply. Because of the larger customer base, routes can be constructed such that truck space is used more efficiently. Consequently the number of used trucks and the fixed cost of performing the transportation orders decrease. Also, order sharing results in a shorter total distance driven (11.9 %). Since variable cost is calculated per kilometre, these costs decrease at the same rate.

	No order sharing		Order sharing		Improvement (%)	
	Avg.	Std. dev.	Avg.	Std. dev.	Avg.	Std. dev.
<b>Cost</b>	9233.0	302.2	8094.2	268.0	12.33	1.61
<b>Variable costs</b>	6306.5	207.0	5554.1	208.7	11.93	1.53
<b>Fixed costs</b>	2926.5	149.7	2540.2	88.2	13.20	4.41
<b># Kilometres</b>	4441.2	145.8	3911.3	147.0	11.93	1.53
<b>Load factor</b>	0.9	0.0	0.9	0.0	3.15	2.52
<b># Trucks</b>	12.9	0.7	11.2	0.4	13.20	4.41

**Table 3.** Results of the routings

<i>Item</i>	<i>Sub item</i>	<i>Definitions and assumptions</i>
<i>Distribution network</i>	Components	The distribution network consists of multiple nodes, each node representing a single client location (i.e. the location where the client order must be delivered). Furthermore, there is one node for the distribution centre. At the distribution centre, the client orders are picked up. A set of arcs represents the road network. There is an arc between each pair of nodes.
	Size of the network	All network components (clients, distribution centre, and roads) are in the 100 x 100-plane
	Units of measure for distance & time	We assume Euclidean distances between nodes. The travel time in minutes between each pair of nodes is proportional to the Euclidean distances, based on a constant speed of 60 distance units per hour. Travel times are relevant since working days of drivers are of limited length.
<i>Clients</i>	Number	Varied between 100 and 380.
	Location	Client locations are chosen randomly in the plane. There can be various degrees of the clusteredness of the client locations (see below).
	Degree of clusteredness	The clusteredness of the client locations is high if many of the client locations are at short distance of each other. When client locations are scattered randomly across the entire plane, the clusteredness is low. For a detailed explanation of the mechanism that is used to generate datasets with different degrees of clusteredness, we refer to the appendix.
<i>Orders</i>	#Orders per client	Each client places exactly one transportation order.
	Order size distribution	We assume the order size to be uniformly distributed on $[\max\{0, X - 25\}, \min\{C, X + 25\}]$ , where X varies between 5 and 245 and C is the truck capacity. Fractional order sizes are rounded to the nearest larger integer.
<i>Distribution centre</i>	Location	In the centre of the plane, at coordinate point (50,50)
<i>Transportation companies</i>	Number	Varied between 2 and 5
	Market shares	The market shares are expressed in terms of the volume that is shipped.
	Location	All trucks start and end their trips at the distribution centre.
	# Trucks per company	Infinite; transportation orders can always be executed
	Truck capacity	Fixed at 250 units
	Fixed costs	The fixed costs per day per truck. We use the Dutch market average of € 225 (NEA, 2003).
	Variable costs	The variable transportation costs per kilometre. We use the Dutch market average of € 1.42 (NEA, 2003).
	Length of working day	Fixed at 10 hours
	Loading/unloading	Each loading activity at the distribution centre and each unloading activity at the client takes 10 minutes
	Number of routes	During a working day, trucks may perform multiple routes

**Table 4.** Characterization of simulation study

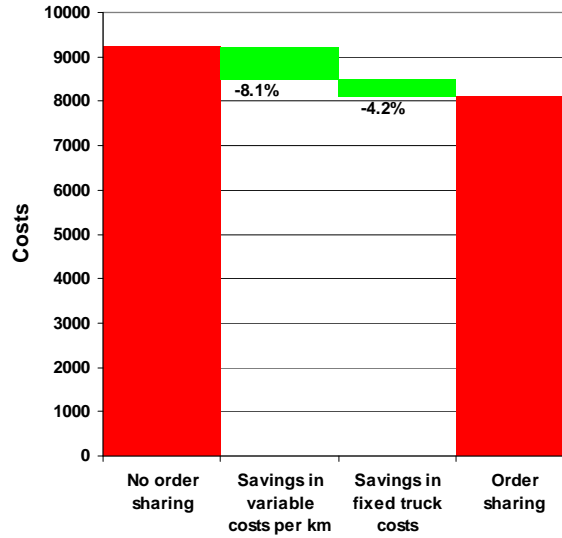


Fig. 3. Savings through order sharing

## 5 Sensitivity analysis

In our specific base case situation, order sharing turns out to be beneficial. However, we found in the case study that a lot of variability exists in the obtained savings. The variability is a consequence of different system characteristics. In this section we investigate the effect on the savings of the most important system characteristics:

- Number of transportation orders in the order set
- Average order size
- Clusteredness of demand points
- Number of transportation companies
- Market share of the “leading” transportation company. The remaining market is distributed evenly among the other companies

For this purpose, we vary one variable at a time and fix the four others at their base case value.

Table 5 defines the range for each variable and the step sizes.

Characteristic	Minimum	Maximum	Step size
Number of orders	100	380	8
Average of uniform order size distribution	5	245	10
Clusteredness of demand points	0	0.99	0.05/0.01 <sup>2</sup>
Number of transportation companies	2	5	1
Market share of “leading” company	0.34	1	0.02

**Table 5.** Range of characteristics values

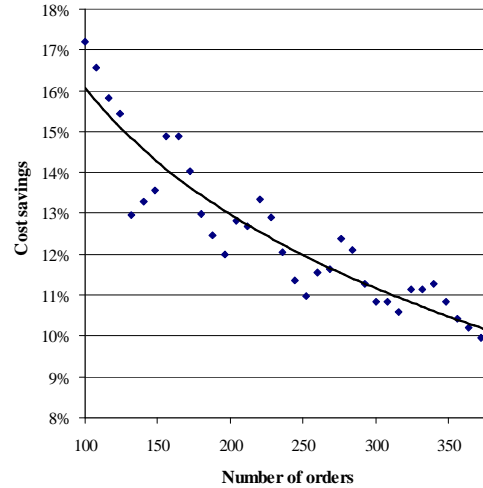
In the following subsections the cost savings resulting from order sharing are one at a time plotted against the characteristics listed in Table 5. Each data point in the plots corresponds to the average result of 50 simulation runs.

### 5.1 *Number of orders*

Figure 4 shows that the cost benefits from order sharing decrease when the number of orders increases. Since all transportation companies have equal market shares, a larger total number of orders implies that the order set of every individual company increases. As a result, each individual company itself has better economies of scale and is able to carry out more efficient routes. However, order sharing remains profitable even with a large number of orders: with order sets of 350 orders, still 10 % of total costs can be saved through order sharing. The deviations from the trend line in Figure 4 are due to fluctuations in the number of trucks that are needed on average with certain numbers of orders. Since in the base case the average order size equals 50, on average 5 transportation orders are transported in one truck.

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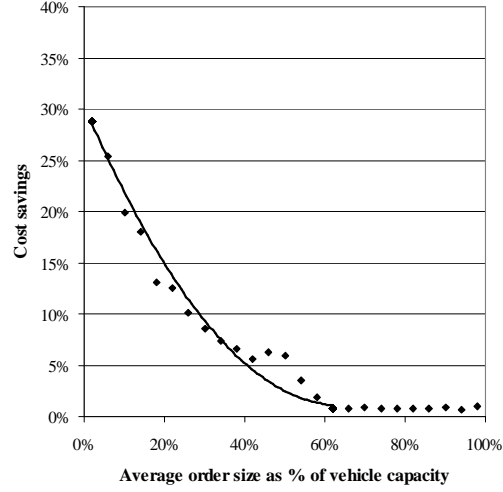
<sup>2</sup> The stepsize is 0.05 on the interval [0, 0.95] and 0.01 on the interval [0.96, 0.99].



**Fig. 4.** Sensitivity of cost savings with respect to the number of orders

## 5.2 Average order size

Figure 5 shows that the cost benefits from order sharing decrease when the average size of the transportation orders increases. When the size is big, a large part of the total order set consists of orders that (nearly) fill a truck. Since we are considering a pure distribution setting, it is often not possible to combine orders in a single route. As a result: we cannot accomplish any savings in kilometres driven for these large orders by means of order sharing. From an average order size of greater than 60 % of the truck capacity on, orders cannot be combined. In this case, the savings from order sharing are limited to a possible decrease in fixed costs, from using fewer trucks. On the other hand, when the average order size is very small, benefits from order sharing are large. In this case, orders from a larger set can easily be combined into routes such that both total route length is shorter and fewer trucks are used.



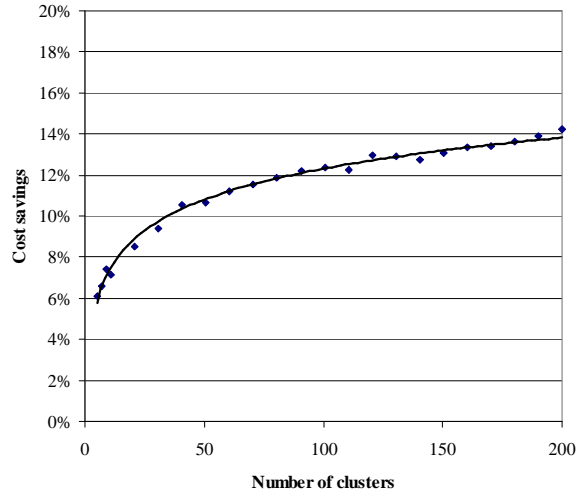
**Fig. 5.** Sensitivity of cost savings with respect to the average order size

### 5.3 Clusteredness of client locations

The level of clusteredness is an indicator for the number of different clusters in which client locations arise. When there are only a few clusters, all 200 clients are located in this small number of clusters and clusteredness is high. On the other hand, when there are 200 randomly located clusters each containing exactly one order, clusteredness is at the lowest possible level. Intermediate values for the number of clusters indicate intermediate levels of clusteredness. We refer to the appendix for a technical explanation of the method we used to generate different levels of clusteredness. Figure 6 shows that the cost benefits from order sharing increase when the number of clusters increases.

Decreasing the clusteredness by introducing more clusters reduces the probability that a single transportation company can combine a pair of clients that are closely located to each other into one route. A better coordination of the route planning through order sharing may result in larger cost savings.

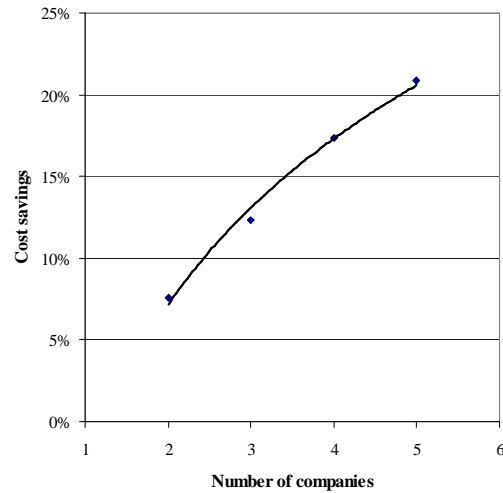




**Fig. 6.** Sensitivity of cost savings with respect to clusteredness

#### 5.4 *Number of transportation companies*

Figure 7 shows that the cost benefits from order sharing increase when more transportation companies participate. When many companies are involved in the transportation of the 200 orders, they all have smaller individual economies of scale. This reduces the possibility to construct efficient routes. So, cost savings are much higher in case many small companies cooperate compared to a situation where only a few big companies cooperate.



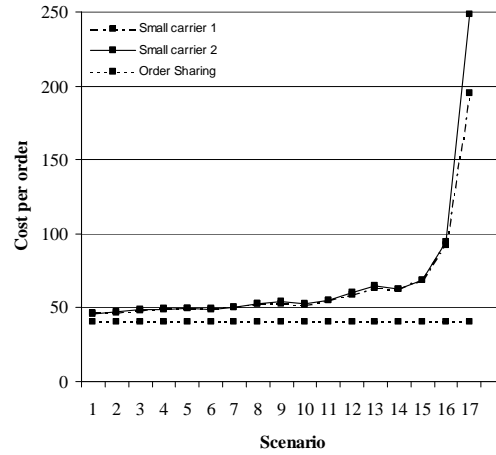
**Fig. 7.** Sensitivity of cost savings with respect to the number of companies involved

### 5.5 Market share distribution

In this section we discuss the influence of the market share distribution on system-wide savings. To this end, we set up 17 scenario's in which we increase the market share of one "leading" transportation company, while we equally spread the remaining market share over the two other carriers (see Table 6). Already without order sharing, the expansion of the "leading" company's market share results in an increasing number of orders that can be combined into efficient routes at the "leading" carrier. This decreases the potential benefits from order sharing between the three companies. On the other hand, as can be seen in Figure 8, order sharing removes the strong inefficiency at the smaller companies.

Scenario	Market share carrier 1 ("Leading" carrier)	Market share carrier 2	Market share carrier 3	Cost savings
1	0.34	0.33	0.33	12.38%
2	0.38	0.31	0.31	12.59%
3	0.42	0.29	0.29	13.10%
4	0.46	0.27	0.27	13.61%
5	0.5	0.25	0.25	12.58%
6	0.54	0.23	0.23	12.12%
7	0.58	0.21	0.21	12.25%
8	0.62	0.19	0.19	12.19%
9	0.66	0.17	0.17	12.34%
10	0.7	0.15	0.15	10.46%
11	0.74	0.13	0.13	10.58%
12	0.78	0.11	0.11	10.81%
13	0.82	0.09	0.09	10.64%
14	0.86	0.07	0.07	8.75%
15	0.9	0.05	0.05	7.00%
16	0.94	0.03	0.03	7.55%
17	0.98	0.01	0.01	0.00%

**Table 6.** Scenarios of market share distribution



**Fig. 8.** Cost per order for the small companies

## 6 Impact of order sharing

We showed in section 4 that for the base case, about 12 % could be saved on transportation costs. This suggests that order sharing is advantageous from an efficiency point of view. However, order sharing has other impacts as well. In this section, without the intention to be exhaustive, we mention some other consequences of order sharing from (i) the clients' perspective, (ii) the transportation companies' perspective and (iii) the perspective of the society. For these viewpoints we discuss both the short-term and the long-term effects.

### 6.1 Clients

The most important variables for customer satisfaction are: price, quality of service and reliability (Moore and Fearon, 1973). In this section we evaluate in which way order sharing between transportation companies affects these elements.

- *Price* - Since the European market for road transportation is highly competitive, in the short run reductions in operational costs of the transportation companies due to order sharing and joint planning are likely to result in lower prices charged to the clients. However, in the long

run bankruptcies may occur at transportation companies that are not able to remain profitable after the price reductions. As a result of the decrease in competition, transportation prices may go up again (e.g. Goodwin, 1999).

- *Quality of service* - With order sharing, better routes can be built from a larger set of transportation orders. Because of this, carriers can work more efficiently and may be able to decrease the total lead-time of a transportation order. This improves the quality of service for the clients. A drawback of order sharing for clients is, that close shipper–carrier relations may disappear.
- *Reliability* – More efficient route planning due to order sharing increases the average load factor of the trucks, leaving less slack. As a result, the system efficiency becomes more sensitive for disturbances, such as traffic jams or delays at the clients. Order sharing has a negative impact on the reliability of service to the clients, because the higher load factors decrease the probability that a given truck can perform an additional transportation order when it arrives. On the other hand, with order sharing clients have a pool of transportation companies at their disposal. In the short run, this would increase the reliability of service, since there are more trucks available for the transportation of an extra order.

## 6.2 *Transportation companies*

Although order sharing clearly improves the efficient use of trucks and the road network, whether or not order sharing increases the long-run profitability of transportation companies depends on the market structure. We are not aware of any publications on the consequences of order sharing for road transportation companies. However, this literature does exist for the airline industry. Morrish and Hamilton (2002) provide a review of this literature. They conclude that order sharing initiatives in the airline industry have not restricted competition and that profitability of the airlines has not been influenced. Practical experience should learn if these findings also hold for road transportation companies.

As a consequence of the more efficient routes, less truck capacity is required. This means that in the short run some capacity of the participating transportation companies becomes redundant. Efforts are therefore needed to find a new function for these trucks. Considering the fierce competition on the European market for road transport, in the long run a number of transportation companies may go bankrupt.

### *6.3 Society*

Our simulation study shows that due to order sharing, the number of kilometres driven decreases. Moreover, the number of used trucks goes down. This implies that the external costs of transport, consisting of e.g. CO<sub>2</sub>-emission, deterioration of the road net, medical costs because of traffic accidents, noise pollution, and congestion (Verhoef, 1994), decrease. On the other hand, road taxes collected by the government decline. Proost et al. (2002) argue that in Europe the ratio between taxes and external costs is such that a decrease in kilometres driven benefits total welfare.

A drawback of order sharing for society in the long run is that some drivers may become unemployed, because of the decline in the number of trucks needed to perform all transportation orders.

## **7 Conclusions and directions for further research**

This paper shows that order sharing is profitable in terms of overall transport efficiency. Cost savings generally range from 5 to 15 % and are sometimes even higher. Taking into account the thin profit margins in road transportation, these cost savings are considerable. Furthermore, we claim that order sharing is especially apt for the transportation of low value goods, since transportation costs make up a relatively high percentage of the total cost price of these goods.

Our results also show that order sharing is more profitable when a large number of transportation companies participate. This insinuates an incentive for cooperation and integration in the sector. In order to cut down costs, carriers may share orders or even merge until a level of scale is reached at which more cooperation is not worthwhile anymore. At that time, a few conglomerates of carriers are likely to remain.

The results of this paper can be used by

- Carriers that are considering a merger and require an estimate of the savings in transportation costs
- Governments wanting to know in which sectors order sharing should be encouraged
- Third or fourth party logistics providers for identifying markets where most value can be created by better coordination of transportation flows

There are several research directions as a consequence of the results. Further research is needed to understand the impact of order sharing in more complex transportation systems. For example, an investigation of how the results will be influenced when factors such as multiple depots, time windows, periodicity or a pick up and delivery set-up are introduced in the analysis would be an important contribution. Another direction is to make a more thorough comparison between our results and the savings that result in practice. In this paper, we reported results of order sharing in the flower transportation sector, but clearly additional insights could be gained from case studies in other sectors. Another extension of this study concerns the organization of an order sharing system. Dullaert et al. state that many transportation companies hesitate to participate in a cooperation because, a) it is unclear when savings will first be realized and how large these savings will be, and b) there is not enough trust that none of the participants are privileged. Hiring an independent party to lead the cooperation may increase trust between the participants. A final direction is a study on *gain sharing*: since savings from order sharing can per definition only be generated when a group of companies cooperate, there is a clear need for a fair allocation mechanism of these savings among the participating companies. This mechanism may be of crucial importance for the success of an order sharing initiative.

## Appendix A: Clusteredness of client locations

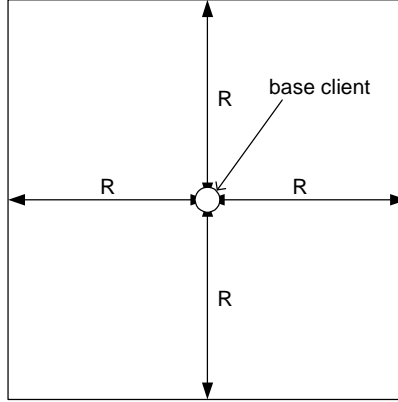
The level of clusteredness is a measure of the spread of client locations over the plane. Client locations are defined to be clustered when we can partition the clients in groups such that:

- between any pair of clients in the same group, mutual distances are short, and
- between any pair of clients that belong to different groups mutual distances are large.

Therefore, clusteredness is low when client locations are scattered randomly over the entire plane and high when client locations are partitioned in a small number of groups.

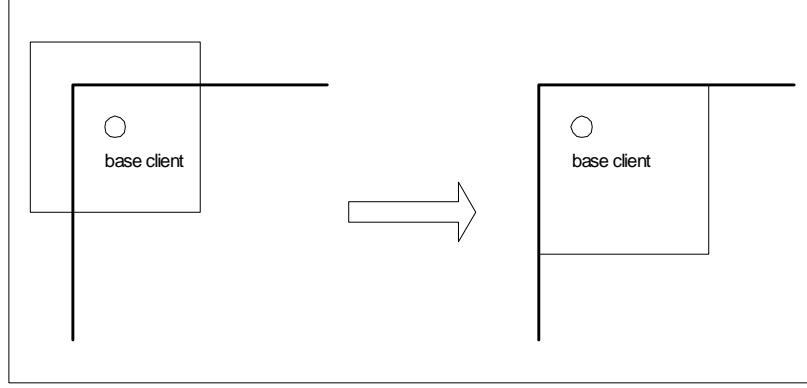
We construct a cluster as follows. A client location is chosen randomly on the plane. This client becomes the *base client* of the cluster and the cluster is placed around it (see Figure 9).

Here,  $R = \lfloor \sqrt{\#orders} \rfloor$ .



**Fig. 9.** A cluster and its base client location

When the cluster base client is placed at a distance smaller than  $R$  from the boundary of the plane in which clients are allowed to be located, we ‘push’ the cluster into the plane. In this way, we ensure that all clusters are of equal size. This is illustrated in Figure 10.



**Fig. 10.** Push cluster region back into the plane

To generate client sets with various levels of clusteredness, we used the following procedure until the required number of client locations is reached:

Step 1 Randomly choose a location for the base client. Define this cluster as the *current* cluster and go to step 3.

Step 2 Choose the next client location randomly within the current cluster and go to step 3.

Step 3 Go to step 2 with probability  $p$  and to step 1 with probability  $1 - p$

This process enables us to influence the level of clusteredness by means of the parameter  $p$ . When  $p$  is close to 1, clients are located in a small number of clusters. On the other hand, when  $p$  is close to 0, most of the client locations will be chosen randomly from the entire plane and clusteredness will be low. The number of clusters containing one or more client locations follows a binomial distribution with mean  $1 + (\#orders - 1)(1 - p)$  and variance  $(\#orders - 1)(1 - p)p$ .



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